



# HASP Student Payload Application for 2012

Payload Title: ARIES-DYNAMICS		
Payload Class: (check one)  <input type="checkbox"/> Small <input type="checkbox"/> Large	Institution:  Inter-American University of Puerto Rico Bayamón Campus	Submit Date:  February 24, 2012
<b>Project Abstract</b> The purpose of the ARIES-DYNAMIC project is to design and to test flight in near space a 1U CubeSat prototype. The main objective is to develop a payload that consists of a Command and Data Handling System (CDHS), an Attitude Determination and Control System (ADCS), and a Global Positioning System (GPS) receiver. The secondary objective is to test the solar panels, a voltage-current characterization board and camera. It is essential to test the Attitude Determination System board and the Control design for the SWIM CubeSat. SWIM is designed to investigate the effects of space weather on the ionosphere; since it will be used as a prototype for 3U SWIM CubeSat currently developed by Inter-American University. Therefore, the ARIES-DYNAMICS ADS will be a test bed for this satellite. The ADCS will obtain data for the sensors, determine the quaternion and perform calculations to move two DC motors, which are attached to the pitch and yaw of the cube. The movements will re-orient the cube to a desired position using a control design, Proportional-Integral-Derivative (PID). It is expected as a result a successful first test in a space environment of the ADS board for the SWIM CubeSat and the completion of the skeleton of the control design, since the SWIM will not use the same actuators. The team currently consists of approximately 12 undergraduate students from many disciplines from the IUPR-Bayamon campus.		
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**ARIES-  
DYNAMICS  
Proposal for the High Altitude Student Platform  
(HASP), 2012**

**Advanced Research and Innovative Experience  
for  
Students Laboratory  
ARIES Labs**



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24 February 2012

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## **Mission Goal**

The SWIM CubeSat is a 3U satellite that uses several subsystems to maintain stability and a pointing accuracy of 0.1 degree due to the science payload, WINCS. The subsystem needed for this is an Attitude Determination and Control; however this system is required to be proven as a reliable subsystem. Therefore an initial testing can be achieved through the HASP platform in a near space environment. The development of this subsystem will also provide knowledge in aerospace engineering to students of the Puerto Rico SWIM CubeSat.

## **Payload description**

### **Objectives**

Nowadays many improvements and advances had been realized on the aerospace sciences. An objective of this project is to increase the knowledge in the Aerospace Sciences specialized in the CubeSat Technology. Another objective is to acquire experience through the accomplishment of the different phases of this project. In particular, an understanding and capability in relationship to the Attitude Determination and Control System (ADCS) implementation. Consequently, the team will be able to obtain educational experience related to ADCS for the Puerto Rico SWIM CubeSat project.

A Science objective is also acquiring measurements of the following parameters; the Earth's gravitational & magnetic fields, the Sun intensity and the angular momentum of the ARIES-DYNAMICS payload. Also, this project will allow learning flight characteristics, such as angular rate rotation and orientation with respect to different reference frames. Another objective is to measure the internal and external temperature during flight to determine the thermal heat transfer at different altitudes. Moreover, is important to obtain an appropriate quaternion representation of the experiment. Finally, obtaining knowledge from the flight data analysis is an important objective of this project.

### **Principal of Operation**

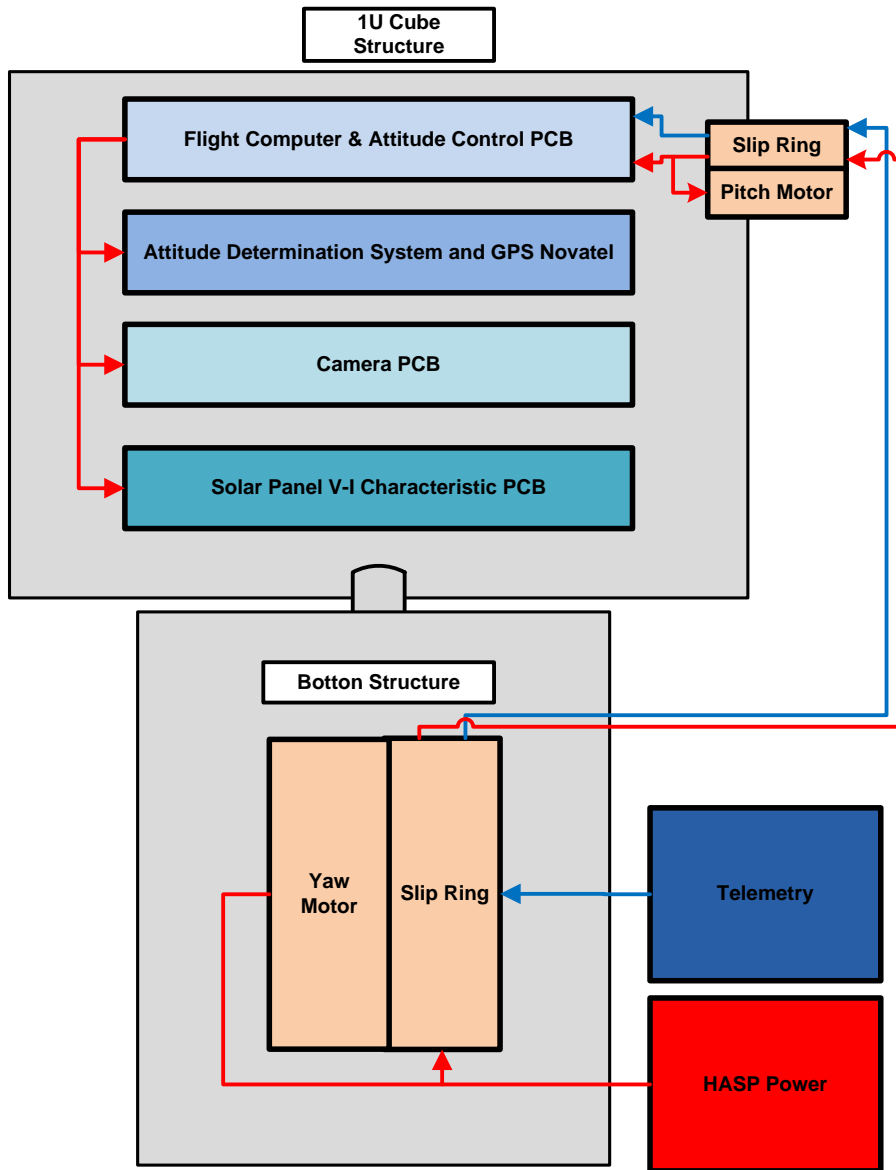
The ARIES-DYNAMICS payload will test an inertial measurement unit (IMU) that could be used for the future SWIM CubeSat project. Once the payload is turned on, the Flight computer and ACS board will reset all the motors to their initial position. All of the boards will be on the top of the cube: 1) an ADS board that will read the data from all the sensors and process it for the control scheme, and will store it in a micro SD card for post analysis; 2) a flight computer that will contain the microcontroller and the ACS circuits; 4) a camera board attached to the bottom cube in that way we can take images of the top cube to ensure that the control system perform its function. In that way we can validate the ADCS operation and perform a post-flight analysis of the stored images to verify the accuracy of the ADCS; 4) a solar panel voltage-current measurement board will be used to obtain the current and voltage of the five solar panels made for the NSF CINEMA UC Berkeley which are placed along the external wall. In the bottom box, only the yaw motor and the slip ring will be present. The attitude quaternion is used to correct the pitch and yaw orientation of the top cube by using the motors. A point in the sky can be chosen as a reference point for the ACS, such as the Sun. The point of doing this is to simulate an ADCS during flight, such as a satellite will do in space.

## **Thermal Control Plan**

The possibility of running the payload in the extreme temperature ranges of  $-80^{\circ}$  -  $60^{\circ}$  C in an altitude of 120,000 feet requires an analysis in the operational minimum and maximum temperature ranges, specially the critical components. Due to previous payload data of HASP 2011 it can be notice that the minimum temperature experienced was  $-80^{\circ}$ C. To ensure an appropriate margin of safety between the temperatures limits an internal temperatures range  $0^{\circ}$  to  $40^{\circ}$  Celsius was selected. Through the analysis and previous experience with HASP payloads it is known that insulation is required to maintain the selected internal temperature range, the insulation required can be Kapton or Multilayer Insulation (MLI). To determine the numbers of Kapton layers for Cold and Hot cases, the thermal design is going to be simulated using Elmer Finite Element Analysis Software in steady-state. As shown in the mechanical design in **Figure 12**, the top motor needs to have an enclosure and a heater. In the other hand, the bottom motor is inside the bottom box, requiring only a heater, both motor covers maybe be insulated by Kapton to ensure a slower rate of heat transfer. The system will be capable of monitoring the internal temperature and will reduce the power generated by setting the mayor components into a standby state when the maximum limit is reached.

## **Mission Justification**

The ARIES-DYNAMICS project is a low cost, low medium-risk test flight to prove new technologies that are critical to the success of the Puerto Rico SWIM CubeSat mission. A flight in the HASP environment allows for a cost effective method to reduce the risk factors to the CubeSat mission. This flight allows the development of new technology and proves the flight software operation in an environment similar to Space. The ARIES-DYNAMICS payload is the next step to obtain a full attitude determination and control system, to characterize the solar panels for the upcoming NSF CINEMA CubeSat project from UC Berkeley, and to validate the usage of MEMS IMU for future CubeSat project.



**Figure 1: System Diagram**

A general description for a system design of the ARIES-DYNAMICS payload is shown in **Figure 1**. The 30V and 0.5A power supply from the HASP platform is connected to the bottom slip ring to pass the power to the top cube through the slip ring. The Flight computer and Control System board in the top cube is the main board since, this board is in charge of supply the voltage and current required for the ADS and GPS board, Camera board , the VI characteristic board and the DC motors. The data from the ADCS will be sent through telemetry and saved in a SD card to be used in the post-processing flight analysis. The ACS will control two motors according to the data received from the ADS board sensors is going to adjust the pitch and yaw angle of the top cube.

## Attitude Determination System (ADS)

A spacecraft in space experience small but persistent external torques. The principal torques is atmospheric drag, solar radiation pressure and the gravity gradient; they will be decreasing the orbit velocity or change the orientation. To determine the orientation of the spacecraft the Earth, the Sun and the stars are used. In addition, inertial sensors such as the gyroscope, also can be carried to provide a short-term attitude reference between external updates. The principal non-gravitational force acting on satellites in Low-Earth-Orbit (LEO) that ranges from (160 – 2000)km, is the atmospheric drag. Drag acts in the opposite direction of the velocity vector, x axis which removes energy from the orbit. Furthermore, the orbit gets smaller which eventually make the satellite to reenter the atmosphere. The solar radiation pressure causes variations in all of the orbital elements. Its effect is strongest for satellites with low ballistic coefficient that is light vehicles with large frontal areas. Finally, by the Newton's law, the attraction of the satellite will be to the center of the Earth, making the satellite closer to Earth. For the SWIM CubeSat is required a pointing accuracy of 0.1. An ADCS compensate for external disturbances and reorient the spacecraft to a desired position.

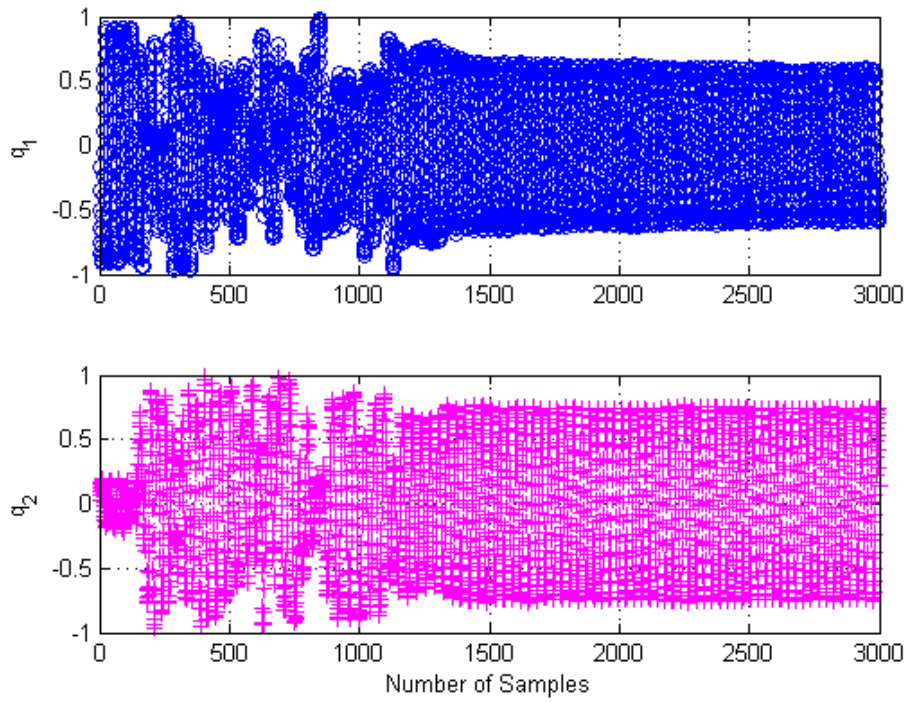
The ADS will be using the accelerometer, magnetometer and gyroscope data to perform a calculation which will describe the rotation and orientation of the platform during flight. Although the project will have solar panels, its data will be not used for attitude determination. Mostly, the solar panel data will be saved in the MicroSD card for post flight analysis. For the gyroscope data the following kinematic equation describes the rotation of the body about its center of mass.

$$\frac{dq}{dt} = \begin{bmatrix} 0 & -\omega_1 & -\omega_2 & -\omega_3 \\ \omega_1 & 0 & \omega_3 & -\omega_2 \\ \omega_2 & -\omega_3 & 0 & -\omega_1 \\ \omega_3 & \omega_2 & \omega_1 & 0 \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \end{bmatrix}$$

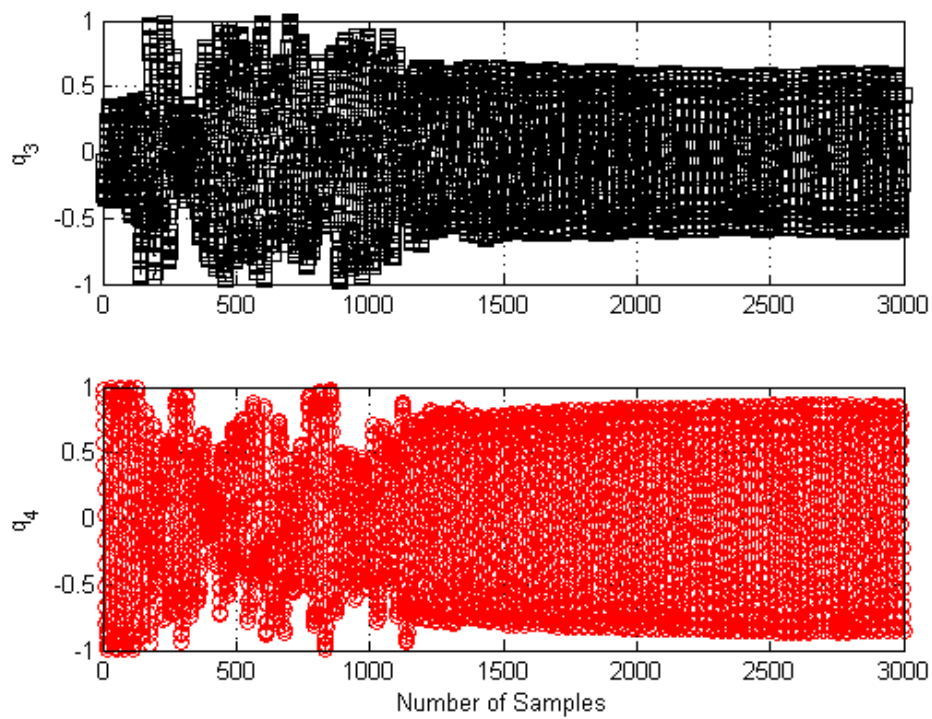
This equation is described in terms of the quaternion and angular velocity. The angular velocity is obtained from an IMU located in the body of the HASP payload.  $\vec{\omega}$  is the angular velocity of the body, and  $q = \vec{q} + q_4$ .  $q$  is the quaternion explaining the orientation of the HASP platform, and  $q_4$  is the magnitude of the rotation of the body. The calibrated data of the gyroscope for the HASP 2010 payload was substituted into equation (1), and it is assumed that the initial quaternion is,

$$q_0 = 0\hat{i} + 0\hat{j} + 0\hat{k} + 1$$

A quaternion is a four component object with a three vector part and a scalar part. For this case the scalar part is 1. The quaternions are used instead of Euler angles to represent rotation due to the simplicity of calculation. In addition, they are simpler to compose and avoid the problem of gimbal lock. Using MATLAB code to integrate the previous equation with the real data taken from HASP 2010 shows the following quaternion components,

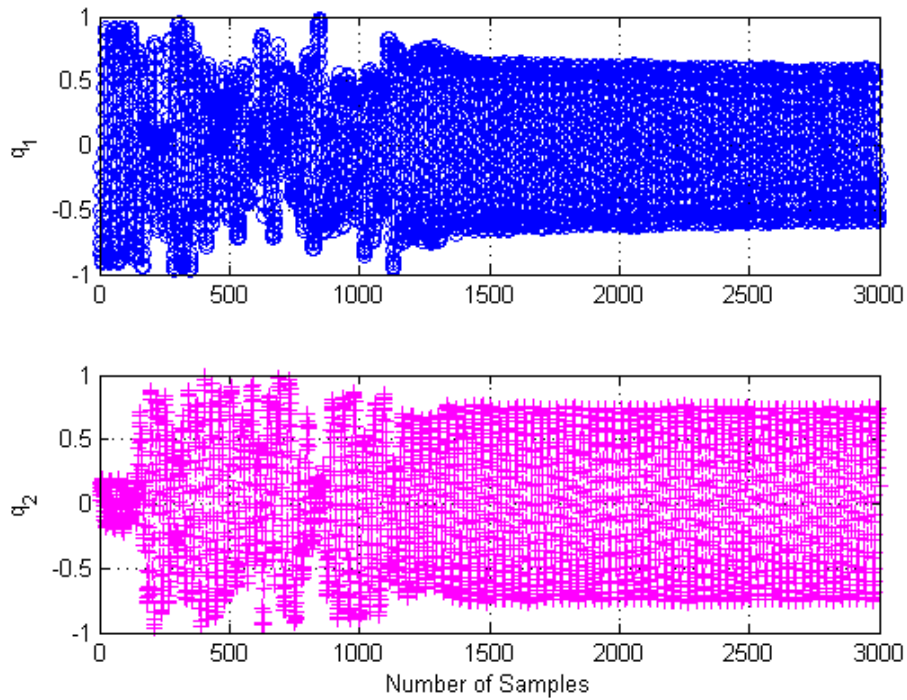


**Figure 2:  $q_1$  and  $q_2$  of the quaternion components**

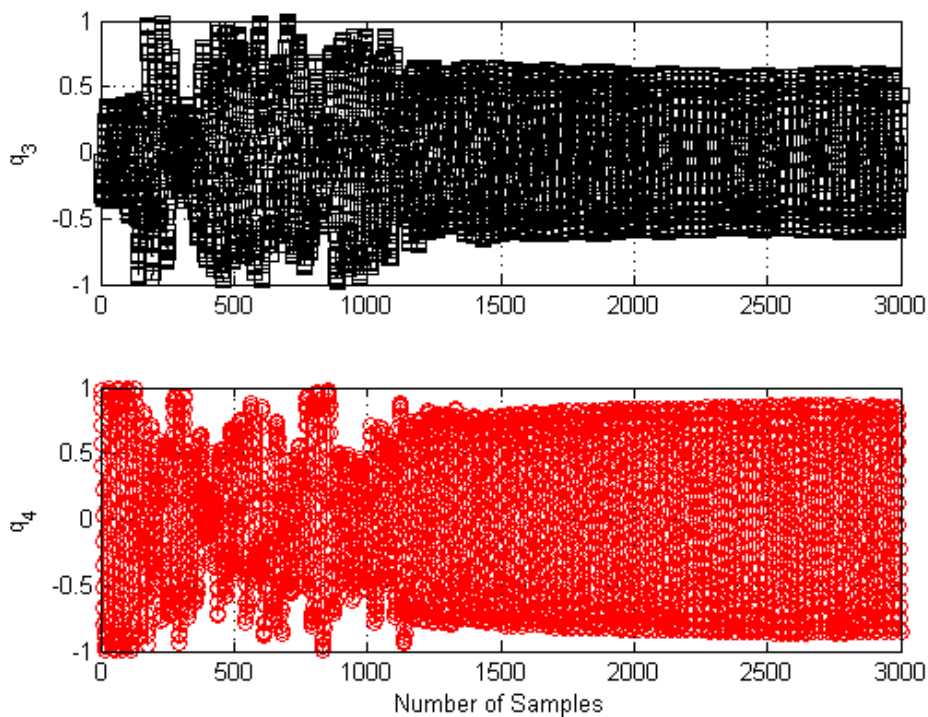


**Figure 3:  $q_2$  and  $q_3$  of the quaternion components**





**Figure 4: q1 and q2 of the quaternion components**



**Figure 5: q2 and q3 of the quaternion components**

As shown for the first 1250 samples is where the HASP was getting altitude and after this point is where it started to have some stabilization, for this range is called Phase 1. This data coincide with the time of two and half hours where after this point the HASP trajectory is more horizontal, for this one is called Phase 2.

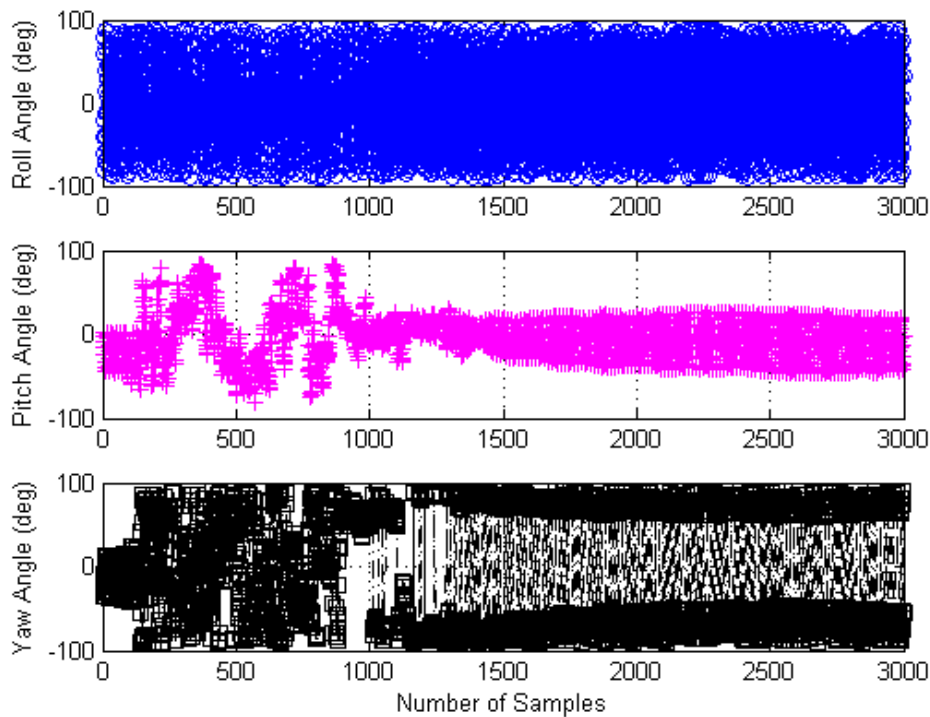
After is performed the rotation using quaternion is then transformed into Euler Angles. The Euler angles provide a better understanding of the satellite motion. The transformation from quaternion into Euler angles can be written as,

$$\sin \theta = 2q_4q_2 - 2q_1q_3 \quad (2a)$$

$$\tan \varphi = \frac{2q_2q_3 + 2q_4q_1}{2q_4^2 + 2q_3^2 - 1} \quad (2b)$$

$$\tan \psi = \frac{2q_1q_2 + 2q_4q_3}{2q_4^2 + 2q_1^2 - 1} \quad (2c)$$

$\theta$  is the pitch angle,  $\varphi$  is the roll angle, and  $\psi$  is the yaw angle. The roll, pitch, and yaw angles describes the rotation about the x, y, and z axis of the payload, respectively. Using these equations, shows the angle motion of the payload. The pitch angle shows that the payload base was rotating from -90 to 90 degrees about the y axis. The roll motion shows a very similar rotation with the yaw axis. For the x and z axis did not occurred a decrease in rotation during the phase 1.



**Figure 6: Euler angles for data of HASP 2011**

The Kalman filter is an algorithm which uses a system dynamic model used to process noisy data retrieved from sensors measurements as an example, to accurately predict an attitude motion of an object in movement. It uses a recursive mathematical model to estimate the state of a process while minimizing any error in the system. The purpose is to force the measured and estimated values for the filter's state to converge and for the difference between the estimate and actual state, to be minimized. The Kalman filter can be represented by the following equation,

$$\bar{X}_k = K_k Z_k + (1 - K_k) \bar{X}_{k-1}$$

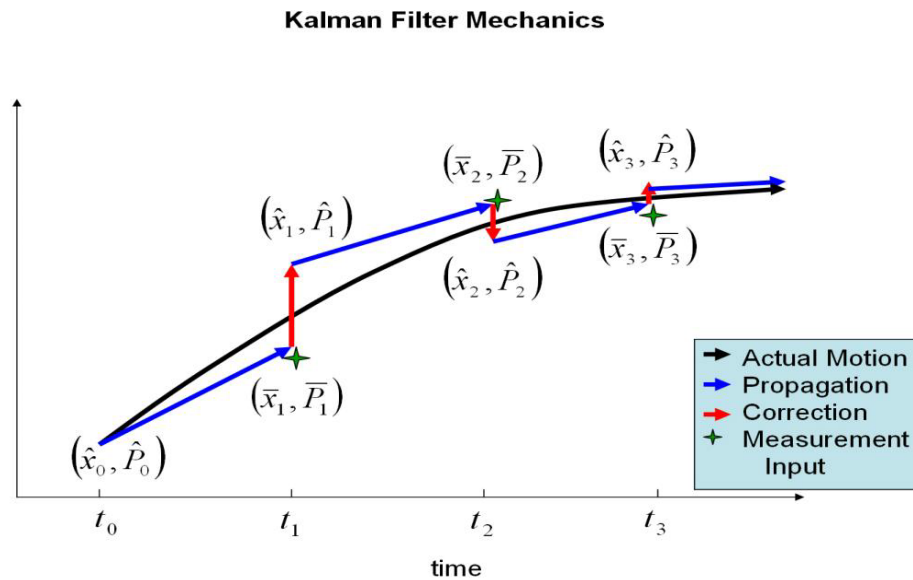
where,

$$\begin{aligned} \bar{X}_k &= \text{current estimation} \\ K_k &= \text{Kalman gain} \quad Z_k = \text{measured value} \\ \bar{X}_{k-1} &= \text{previous estimation} \end{aligned}$$

and the k subscript are states or in state vectors,

$$\begin{aligned} x(k) &= Ax(k-1) + Bu(k-1) \\ P(k) &= AP(k-1)A' + Q \end{aligned}$$

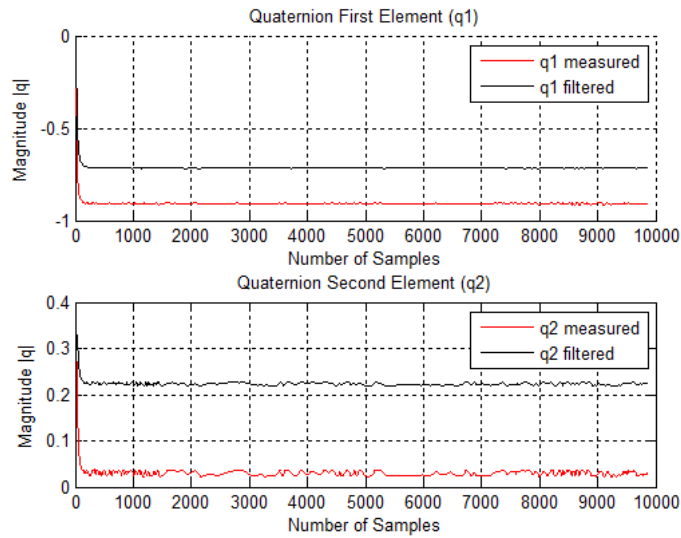
where P is the initial value of covariance and Q is the process noise covariance.



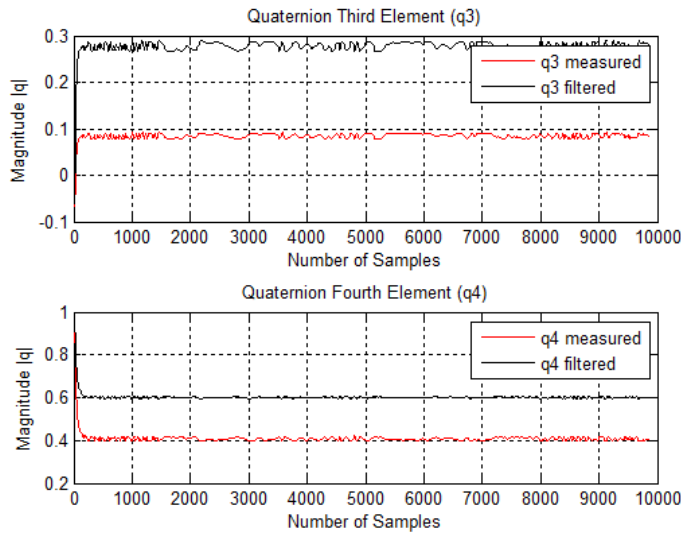
**Figure 7: Kalman Filter process for converging on a true state vector**

**Figure 7** shows a graph representation of what the Kalman Filter performs. The y-axis represent the position and the x-axis the time. Each new step will try to correct its error using the previous value. The Kalman Filter can be used together with the Gauss-Newton method. The Gauss-Newton method is used to solve non-linear least squares problems. This method uses  $B_k = J_k^T J_k$  where  $J_k$  is the Jacobian matrix. Its advantage is that for a second derivative which can be difficult to compute is not required.

Using the data from HASP 2011 was implemented the Kalman Filter as shown in **Figure 8** and **Figure 9**. The data presented of the quaternion is normalized. Each time a conversion from Euler Angles to quaternion and in reverse operation to the result can be added some error. Because of this error that can be added the quaternion are normalized as shown in the figures below.



**Figure 8: q1 and q2 of the filtered quaternion components**



**Figure 9: q3 and q4 of the filtered quaternion components**

The quaternion graphs which contain the quaternion components separately showed a bias with respect to the measured and filtered quaternion values. This is due because most of the gyroscope has a bias offset also known as the null voltage and is the measured voltage when the gyro is not rotating about its axis. The gyro output voltage measurements above the bias offset indicate rotation in one direction, while voltage measurements below the bias offset indicate rotation in the opposite direction.

## Attitude Control System

The Attitude Control System stabilizes the cube and orients it in desired direction using active actuators. In space can be used active or passively. The SWIM CubeSat will be using a magnetotorquer and a reaction wheel. Our project will be using two DC motors to compensate for the rotation of the HASP platform.

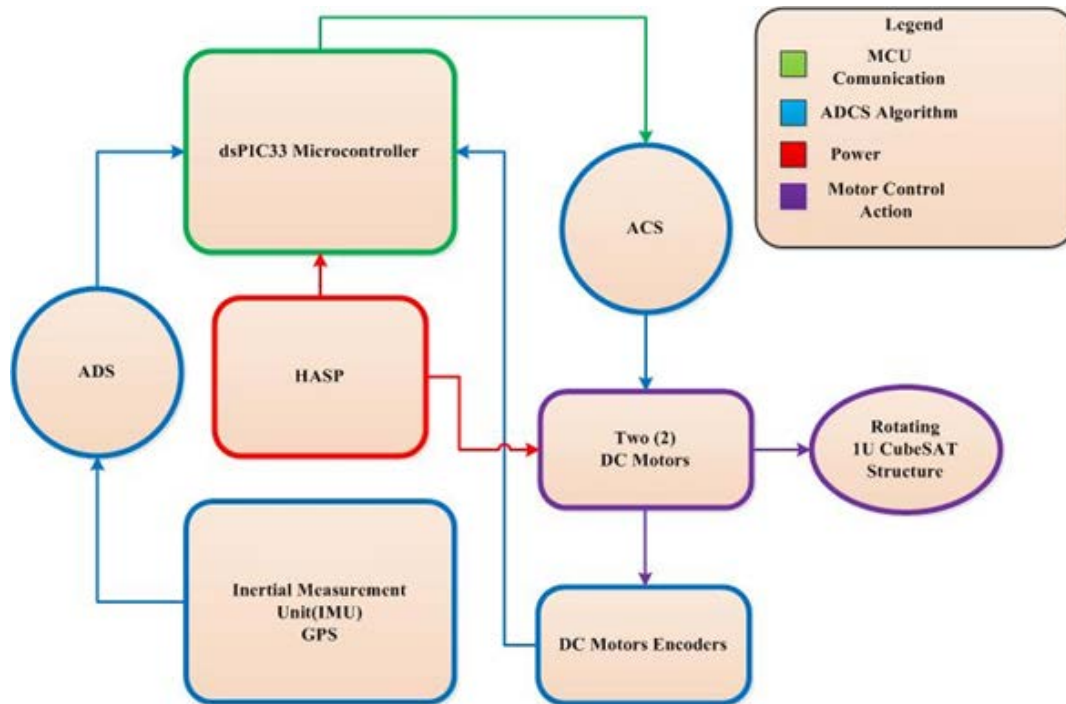


Figure 10: Control System Diagram

An extensive research for the previous Puerto Rican HASP 2011 payload has been done to design an Attitude Control System (ACS) to test various sensors. To obtain the orientation of the payload, the angular velocity, Earth's magnetic field, and the acceleration will be used to obtain the Euler's angles from the quaternions calculated by a Kalman filter.

The objective of the control system is achieved by two DC motors that control the pitch and yaw orientation of the top cube. These two angles are determined by the microcontroller with two encoders which receive the actual yaw and pitch angles. Then, these angles are used to compare the measurements to the set points such that the error between the measurement and the set point becomes a minimum. It is important to note that all the signals coming in or out of the microcontroller are sampled and hold to serve the control objective.

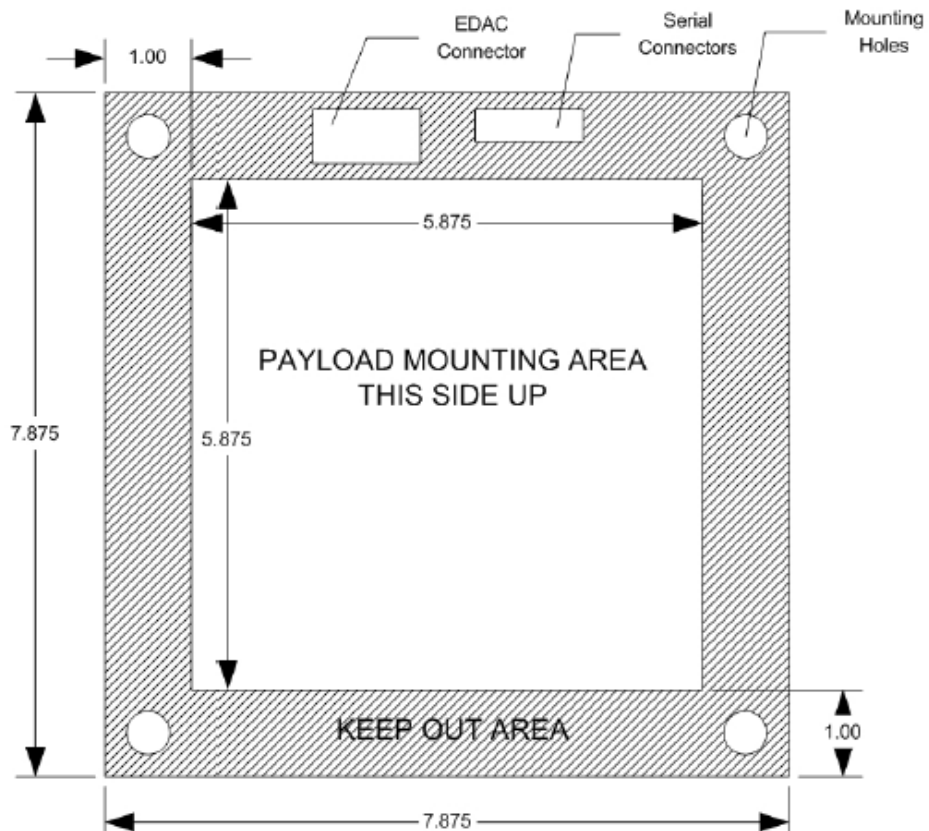
## Payload Specifications

### HASP Power Supply

The primary available power source during flight is a 30V at 0.5A from HASP. The main purpose of the project is to test the functionality of the ADCS; therefore the HASP will provide the necessary power for these critical components during the (approximately) 17hr flight.

### HASP Power Interface

The HASP mounting plate provides two connectors: one connector is the DB9 serial connector used for uplink and downlink of data; and the other connector is the EDAC 16 connector which provides the connections for power, the discrete commands to the HASP platform, and the analog outputs. **Figure 3** shows the platform and the location of both connectors.



**Figure 11: HASP Mounting Area Layout**

The EDAC is a 20 pin connector used to interface our system to the HASP 30V power. The HASP already provides this connector in its platform, and the wires are labeled with a specific color to identify its function. The following table describes the wire and its function (taken from HASP Interface Manual):

Function	EDAC Pins	Wire Color
+30 VDC	A,B,C,D	White with red stripe
Power Ground	W,T,U,X	White with black stripe
Analog 1	K	Blue
Analog 2	M	Red
Signal Return	L, R	Black
Discrete 1	F	Brown
Discrete 2	N	Green
Discrete 3	H	Red with white stripe
Discrete 4	P	Black with white stripe

**Table 1:- EDAC 516-020 Pin Layout**

The table shows four wires that provide +30VDC; these wires are labeled as A, B, C, and D. These wires are required to be connected in parallel to allow the maximum current (0.5Amps) from the HASP. The parallel connections between the wires should be connected properly to the step down circuit on the Flight computer/ACS board.

### **Payload's Power Budget**

Sensors	Voltage (V)	Current (A)	Power (W)	Power Source
Digital Temperature Sensor DS18B20	3.3	0.006	0.0198	HASP
DSPIC33F256MC710 Microcontroller	3.3	0.05	0.165	HASP
MPU 6000 IMU	3.3	0.0038	0.01254	HASP
Real Time Clock DS1306	5	0.00128	0.0064	HASP
SD card circuit	3.3	0.038	0.1254	HASP
CMOS Camera	5	0.025	0.125	HASP
Solar Panels Electrical Components	5	0.114	0.57	HASP
RS232	3.3	0.03	0.099	HASP
Honeywell Magnetometer	3.3	0.0008	0.00264	HASP
Atmega 2560	5	0.05	0.25	HASP
GPS Lassen IQ	5	0.32	1.6	HASP
Antenna	5	0.05	0.25	HASP

**Table 2: Power Budget**

The total current consumption in the payload is delivered by the HASP platform. This voltage is then converted by a DC to DC voltage converter from a 5V to 3.3V power source depending on the sensors configuration. Because, the 30V provided by the HASP are dropped to 5V and 3.3V respectively the current can be increased. In summary, the resulting power consumption will be around 4.0488 W which is fine because the HASP can provide a total power of 15W.

### Downlink Telemetry Specifications:

The Aries Dynamics Payload will have a serial data downlink stream format, the approximate downlink will be obtained by the number of bytes divided 8bits to obtain the amount of bytes per second. The data obtained from the ADS board in which consists of a GPS and an IMU at this moment. The GPS used is the OEMV-1 and the IMU is the ADIS16488, which outputs the gyroscope, accelerometer, delta angle, delta velocity, and barometer output data registers that uses a 32-bit, twos complement format. The GPS receiver will obtain selected data from two sentences, the RMC and GGA. **Table 3** shows the total of bytes of one row (sample) of data from the ADS board. This will be done for the ACS board that will be connected through the PC/104 bus. The total bytes required for the flight is determined by the quantity of the sensors and the total bytes of the measurement of the sensor times the hours the payload that it may remain in flight. Thus greater detail will be explained in the design document.

Byte	Description	Device
1-17	Time Stamp	RTC
18	Comma Separator	
19-21	Accelerometer: X axis	Inertial Measurement Unit ADIS16488
22	Comma Separator	
23-25	Accelerometer: Y axis	
26	Comma Separator	
27-29	Accelerometer: Z axis	
30	Comma Separator	
31-33	Gyroscope: X axis	
34	Comma Separator	
35-37	Gyroscope: Y axis	
38	Comma Separator	
39-41	Gyroscope: Z axis	
42	Comma Separator	
43-45	Magnetometer: X axis	
46	Comma Separator	
47-49	Magnetometer: Y axis	
50	Comma Separator	
51-53	Magnetometer: Z axis	
54	Comma Separator	
55-57	Temperature	
58	Comma Separator	
59-61	Pressure	
62	Comma Separator	
63-65	Delta Velocity	
66	Comma Separator	
67-73	Internal Temperature Sensor	DS18B20
74	Comma Separator	
75-136	GPS Data	OEMV-1
137	End of Line	-----

**Table 3: Serial Data Record per second**



The data will be saved in the SD card. The SD card will be formatted FAT 16 before use. The program will use the SD Fat library to create an object to access Fat16 files in SD cards. The data will be saved as a comma separated values (CSV) format.

## Uplink Commanding Specifications:

The ARIES DYNAMICS payload will require command uplink capability. Below a list of Uplink commands:

**A. Uplink Command List:** This list should contain all of the commands for your payload.

### 1. Wake Up Command:

Command Name:	ON
Hex Command Byte:	4F
Description:	Wakes up the payload from sleep
Critical?	Yes
Payload Response Message:	"Command Received: ON"

### 2. Sleep Command:

Command Name:	OFF
Hex Command Byte:	46
Description:	Puts the payload on sleep mode
Critical?	Yes
Payload Response Message:	"Command Received: OFF"

### 3. Heater On Command:

Command Name:	HON
Hex Command Byte:	48
Description:	Turns on the heater
Critical?	No
Payload Response Message:	"Command Received: HON"

### 4. Heater Off Command:

Command Name:	HOFF
Hex Command Byte:	68
Description:	Turns off the heater

Critical?	No
Payload Response Message:	"Command Received: HOFF"

**5. NULL Command:**

Command Name:	NULL
Hex Command Byte:	00
Description:	Terminates listening mode
Critical?	No
Payload Response Message:	"Unrecognized or NULL command"

**Example of Command Transmission String**

Here is an example of the TON command string in hexadecimal format:

“01028054030D0A”

Byte	Hex Value	Description
1	01	Start of Heading (SOH)
2	02	Start of Text (STX)
3	80	Payload ID + Checksum
4	54	Hex Command Byte
5	03	End of Text (ETX)
6	0D	Carriage Return (CR)
7	0A	Line Feed (LF)

**Weight Budget**

The ARIES-DYNAMICS payload has a weight limit of 3kg for all the components; therefore, it is required to develop a weight budget to monitor the weight of the entire payload. The approximate weight of each one of the components for the payload is described in **Table 4**. Since this project is currently in the preliminary phases, there are several weights that are to be determined. Nevertheless, more detailed weight information is present in the CDR document for this project and the final weight information of the components will be included in the FRR document.

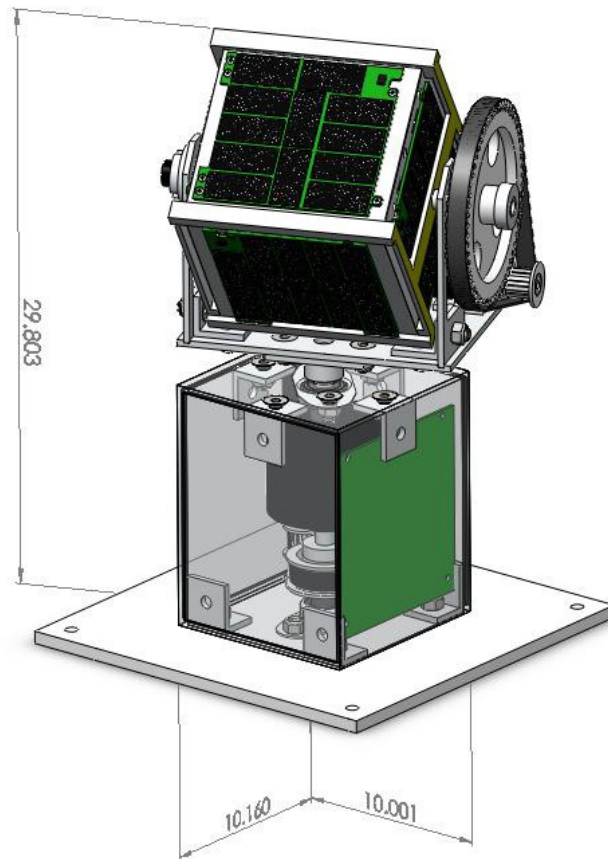
Total Weight of HASP Components	
Weight (g)	Instruments/Components
157	Panel Solar
80	Caps Superior and Inferior
146.4	ADS Board
186.4	ACDS Board
550	Payload platform
354.8	Bottom Box
308.2	Two Motors
42	Two Pitch Towers
89	Damper
47	Side Cage
40	Motor Cage
43	Servo Motor
117.13	CubeSat
283.8	Slip Ring + Bottom Damper
7.8	Pulley
3.1	Bottom Pulley
9.5	Two Bearing in Columns
86.89	Platform for Columns
19	Two Bearing in Bottom Box
122.24	Heating Palate + Empty Board
13.3	Principal Rod
<b>2706.56</b>	<b>Total</b>

Table 4: Weight Budget

## Preliminary drawings

### Payload Dimensions and Design

The ARIES-DYNAMICS experiment must comply with various requirements such as weight and power. This size must be met since the payload should not exceed a 15x15 cm footprint, a height of 30cm, and the ability to survive the landing loads. The weight, the yield strength, and the size are taken into account in the design process. The ARIES-DYNAMICS payload is mounted to the interface plate with four bolts from below. The design in **Figure 12** is developed to allow movements in two dimensions (yaw and pitch motion).



**Figure 12: Mechanical Design**

## **Testing and Integration Procedures**

### **Testing at Inter American University of Puerto Rico Bayamón Campus**

The ARIES-DYNAMICS payload requires environmental testing to perform instrument calibration and flight system validation. This project will be tested in extreme temperatures to ensure that the payload will perform successfully throughout the entire flight. According to the temperature profile of previous IUPR HASP payloads (EQUIS and TigreSAT); it is necessary to perform these tests in a temperature range of  $-80^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$  for a 6 hour period. A physical prototype of the experiment will be developed and tested in a thermal vacuum chamber at the Inter American University of Puerto Rico. The test will simulate the cold and hot environments to do any adjustments with time if it is necessary. By doing this, the team will be prepared to pass and complete the integration process as efficiently as possible in the NASA Columbia Scientific Balloon Facility.

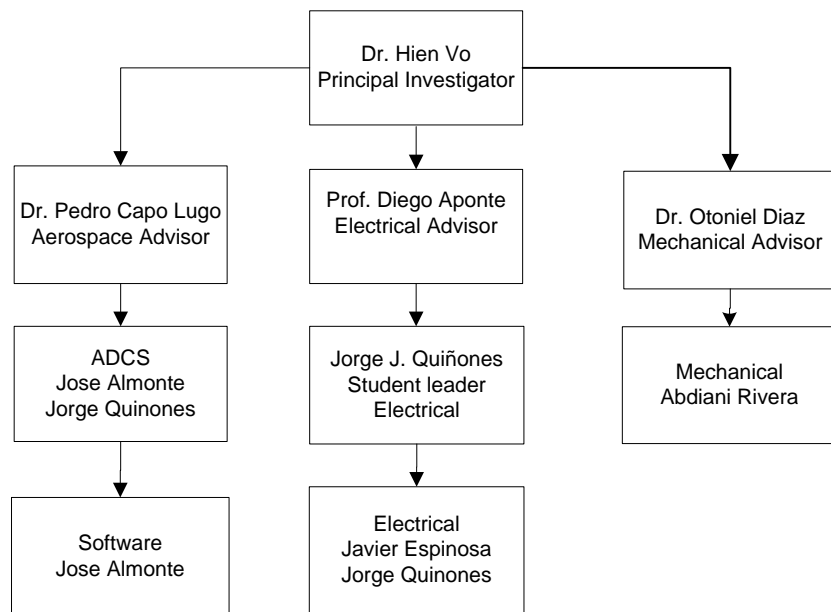
The expected integration process for the Aries-Dynamics at the Columbia Scientific Balloon Facility will be consisting of the following step:

- Mount payload to HASP platform.
- Connect the payload bottom box slip ring, to the HASP power (30V@.5A) and serial data pins from the EDAC connector. To provide connection to the other slip ring on the top cube to power on the systems.
- Verify that the power system is working properly and supplying the require operating voltage of every subsystem.
- Verify the communication to and from HASP platform.
- Turn on flight computer and run the initial setting configuration.
- Verify the flight computer performance and enable all subsystems.
- Verify and monitor temperature sensors readings and turn on/off heater if necessary.
- Verify motor functionality and encoders readings.
- Perform thermal and vacuum test.
- Troubleshoot for any faults on electrical or communication systems.



## Management

This project will operate under the supervision of Dr. Hien Vo as shown in **Figure 13** at the Inter American University of Puerto Rico. Professors and a NASA engineer are supervising the work done by the student groups. The focus of the Aerospace Research and Innovative Experience for Students (ARIES) is to allow students to participate in a real space engineering project and to better prepare the student for careers in aerospace engineering. Additionally, the main motivation is to create an environment where creativity and independence is encouraged, allowing to apply the theory from the classroom to a real hands on work.



**Figure 13: ARIES-DYNAMICS Students and Faculty**

**Gantt Chart:**

Task Name	Duration	Start	Finish	Task Name	Duration	Start	Finish
Capstone Proposal	50 days	Mon 12/12/11	Fri 2/17/12	Hasp Proposal Comments Review Due date	11 days	Fri 2/10/12	Fri 2/24/12
GPS and IMU Research	0 days	Mon 1/16/12	Mon 1/16/12	Feb Monthly Report	17 days	Wed 2/1/12	Thu 2/23/12
Develop Schematic for ADS Board	8 days	Wed 2/1/12	Fri 2/10/12	Comment Review and Monthly Report	1 day	Fri 2/24/12	Fri 2/24/12
Attitude Determination in Matlab/Simulink	11 days?	Fri 2/10/12	Fri 2/24/12	Develop a Control circuit to circuit (SCH & BreadBoard)	15 days	Mon 2/27/12	Fri 3/16/12
Create Pumpkin PC/104 Foot print	3 days	Fri 1/27/12	Tue 1/31/12	Develop a SCH for control and Flight computer(together)	17 days	Mon 2/27/12	Tue 3/20/12
Create GPS component in eagle	14 days	Fri 1/27/12	Wed 2/15/12	ADCS to C code	25 days?	Sat 3/24/12	Thu 4/26/12
Create ADIS16488 Component in eagle	7 days	Tue 2/7/12	Wed 2/15/12	Create PCB layout for Control & Flight Computer Board	20 days	Tue 2/28/12	Sat 3/24/12
Determine 104 Bus Pin Configuration	24 days	Tue 1/17/12	Fri 2/17/12	Preliminary Design Review	51 days	Mon 1/2/12	Fri 3/9/12
Attitude Control in Matlab/Simulink	20 days?	Sat 2/25/12	Thu 3/22/12	Design review Report	1 day	Wed 3/28/12	Wed 3/28/12
Create PCB Layout	8 days	Fri 2/17/12	Mon 2/27/12	Monthly Progress Report	1 day	Fri 3/30/12	Fri 3/30/12
Verify and Order PCB	9 days	Tue 2/28/12	Fri 3/9/12	Populate and TestPCB Boards	20 days	Mon 3/26/12	Fri 4/20/12
Solder Components and PCB Testing	35 days	Mon 3/12/12	Thu 4/26/12	Midterm Capstone Report and Critical Design Review	1 day	Mon 4/9/12	Mon 4/9/12
Monthly Progress Report	0 days	Fri 1/27/12	Fri 1/27/12	Pre Payload Specifications and Integration Plan	1 day	Fri 4/20/12	Fri 4/20/12
Capstone Meeting wt Faculty	1 day?	Mon 2/6/12	Mon 2/6/12	Monthly Progress Report	45 days	Mon 2/27/12	Thu 4/26/12
Test motor performance with actual load to determine required voltage	10 days	Fri 2/17/12	Wed 2/29/12	Final Payload Specifications and Integration Plan	1 day	Fri 6/22/12	Fri 6/22/12
Design Review/Proposal Defense Presentation	12 days	Thu 2/9/12	Fri 2/24/12	Monthly Progress Report	1 day	Fri 6/29/12	Fri 6/29/12
Capstone Team Meeting	1 day	Tue 2/7/12	Tue 2/7/12	Flight Operation Plan and Monthly Progress Report	1 day	Fri 7/27/12	Fri 7/27/12
Final Proposal Report	1 day	Wed 2/8/12	Wed 2/8/12	Capstone Final Presentation	10 days	Mon 4/23/12	Fri 5/4/12
Select Components for ACS Hardware	5 days?	Mon 2/20/12	Fri 2/24/12				
Proposal Defense Presentation	1 day	Wed 2/22/12	Wed 2/22/12				

**Figure 14: Timeline of ARIES-DYNAMICS project**